CVD DIAMOND THIN FILM TECHNOLOGY FOR MEMS PACKAGING

Xiangwei Zhu, Dean M. Aslam

Electrical and Computer Engineering, Michigan State University, E. Lansing, MI 48824, USA

Phone: (517)-432-5648, E-mail: zhuxiang@egr.msu.edu

Keywords: Diamond, Thin Film Package, Integrated, MEMS.

Abstract

Due to its extreme hardness, chemical and mechanical stability, large band gap and highest thermal conductivity, poly-crystalline diamond (poly-C) is expected to be an excellent packaging material for biomedical and environmental MEMS devices. Recent wafer-level MEMS packaging approaches can be characterized into two categories; integrated encapsulation process[1] and wafer bonding process[2]. To apply poly-C MEMS technology on packaging, in addition to thermal management application as heat sink[3], a fabrication technology of all-diamond packaging panel with built-in interconnects (boron-doped poly-C) was reported[4]. This paper reports, for the first time, the development of poly-C thin film packaging technology which is integrated into the post-MEMS encapsulation process. Boron-doped poly-C is studied as a material for feedthroughs, which is embedded in undoped insulating poly-C package.

DESIGN CONCEPT

A diamond thin film package for MEMS devices, depicted in Figure 1 (a), is fabricated using a 3-mask process (Figure 1 (b)). After a 1-µm-thick boron-doped poly-C film is deposited and patterned for feedthroughs, a 4-µm-thick poly-C film is deposited on 4-µm-thick sacrificial PECVD oxide. The poly-C film is patterned with fluidic access ports for the releasing of the package. These access ports are used to seal the package in final step consisting of additional poly-C growth, which will only grow on existing poly-C layers.

PACKAGE FABRICATION

A typical poly-C film fabrication involves seeding, growth and patterning. For seeding, diamond powder with an average particle size of 100 nm was applied on the sample surface using a diamond-loaded photoresist (DPR) technique[5]. Then, a poly-C thin film was grown using MPCVD system in a CH_4:H_2 (1.5 sccm : 100 sccm) gas mixture environment with 40 torr pressure at temperature of 730 °C. The Raman spectra taken on the deposited poly-C film show a sharp sp^3 peak at 1332 cm^{-1}, indicating high sp^3/sp^2 ratio. A microwave electron-cyclotron-resonance (ECR) RIE system was used to dry-etch the poly-C film using the parameters shown in Table 1. The poly-C feedthroughs were doped in-situ using tri-methyl-boron diluted in hydrogen (0.098%) as the source of boron. This doping technique leads to resistivities in the range of 0.003 – 0.31 Ω-cm[4]. The resistivity of the poly-C feedthroughs film in the test package (Figure 2) was 0.02 Ω-cm.

RESULTS AND SUMMARY

Figure 2 shows the first generation of fabricated diamond package. Fluidic access ports for etching were studied as shown in Figure. 2 (c) – (d). The poly-C thin film experienced compressive stress after release. Films with zero-strains can be fabricated by adjusting the growth conditions. During the sealing of access ports, poly-C will only grow on the areas consisting of poly-C, with typical sealing pressures of 40 torr (the poly-C growth pressure). For packages requiring lower pressures, ECR CVD diamond growth, reported at 10 mtorr[6], can be used for the final sealing step. A new set of masks is being designed which can help to optimize the releasing of the package and sealing of the package under lower pressures. The poly-C thin film packaging technology is being reported for the first time and is expected to provide new structures/concepts in the MEMS packaging.

Table 1. ECR plasma etching parameters

Gas Flow Rate (**sccm**)			Microwave Input Power (**W**)	RF Power (**W**)	DC Bias (**V**)	Chamber pressure (**mtorr**)	Typical Etch Rate (**μm/hour**)
Ar	O_2	SF_6					
8.0	28.0	2.0	400	100	-130	5	4.5

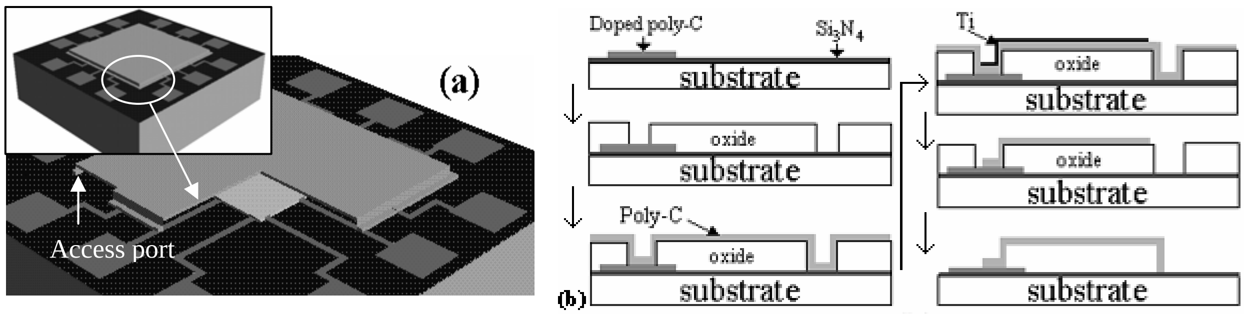

Figure 1 (a) Basic Concept and Cross-section view; (b) fabrication process.

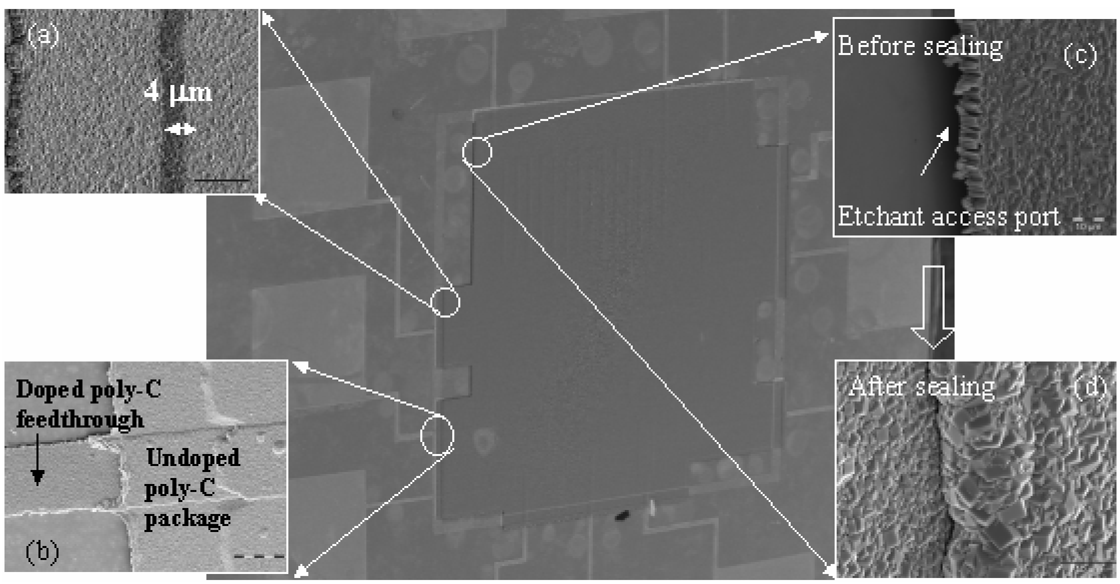

Figure 2 Fabricated poly-C thin film package; insets are close view of (a) package border, (b) poly-C feedthrough and (c) – (d) Study of etchant access port.

REFERENCES

1. Liwei Lin, R.T. Howe and A.P. Pisano, “Microelectromechanical filters for signal processing”, *Journal of Microelectromechanical Systems*, Vol. **7**, pp. 286 (1998).
2. B. Stark and K. Najafi, “A low-temperature thin-film electroplated metal vacuum package”, *Journal of Microelectromechanical Systems*, Vol. **13**, pp. 147 (2004).
3. K. A. Moores, and Y. K. Joshi, “High Performance Packaging Materials for Improved Thermal Management of Power Electronics”, *Future Circuits International*, Issue **7**, pp. 45 (2001).
4. X. Zhu, D. M. Aslam, Y. Tang, et al., “The fabrication of all-diamond packaging panels with built-in interconnects for wireless integrated microsystems”, *Journal of Microelectromechanical Systems*, Vol. **13** pp. 396 (2004).
5. G. S. Yang, M. Aslam, “Ultra-High Nucleation for Growth Smooth Diamond Films”, *Appl. Phys. Lett*. **66,** pp. 311 (1995).
6. C. R. Eddy Jr., D. L. Youchison, B. D. Sartwell, K. S. Grabowski, “Deposition of diamond onto aluminum by electron cyclotron resonance microwave plasma-assisted CVD”, *J. Materials Research*, Vol. **7**, No. 12 pp. 3255 (1992)